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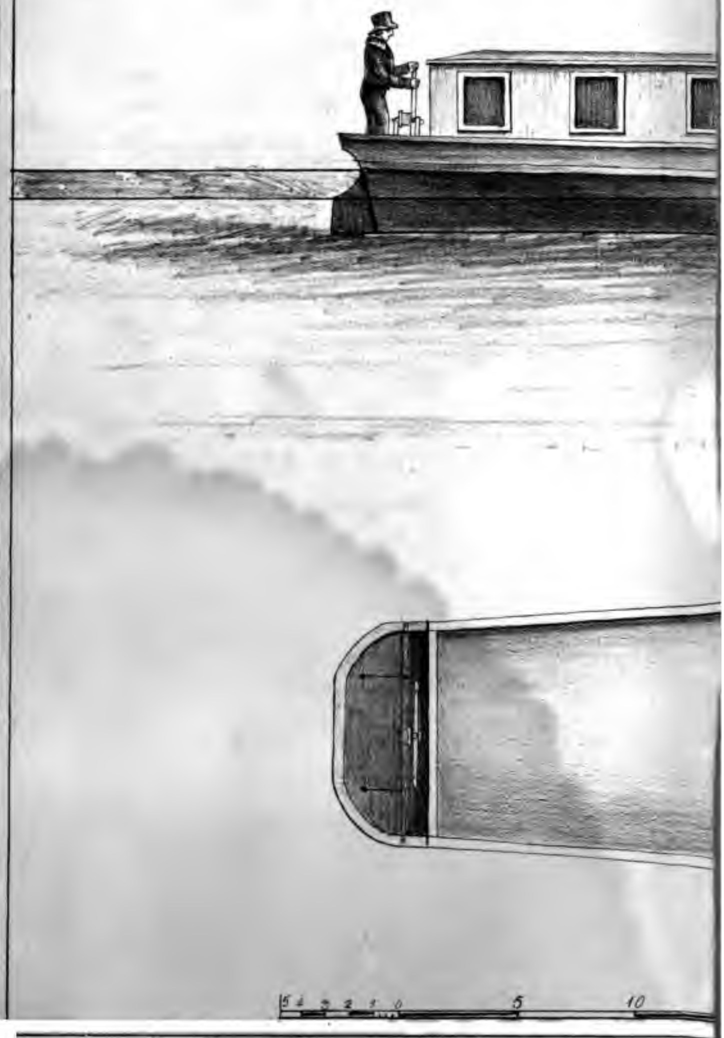

REMARKS

ON

CANAL NAVIGATION,

ILLUSTRATIVE OF THE ADVANTAGES OF THE USE

OF STEAM,

AS A MOVING POWER ON CANALS.

WITH

AN APPENDIX,

CONTAINING

A SERIES OF EXPERIMENTS, TABLES, &c. ON WHICH A NUMBER OF PROPOSED IMPROVEMENTS ARE FOUNDED.

ALSO,

Plans and Descriptions

OF

CERTAIN CLASSES OF STEAM BOATS, INTENDED FOR THE NAVIGATION OF CANALS, AND THE ADJOINING BRANCHES OF THE SEA.

BY WILLIAM FAIRBAIRN,
Engineer.

LONDON:
LONGMAN, REES, ORME, BROWN & GREEN;
CADELL & Co. AND JOHN FAIRBAIRN, EDINBURGH;
SMITH & SON, GLASGOW;
AND
ROBERT ROBINSON, MANCHESTER.

MDCCCXXXI.

TO

THOMAS GRAHAME, ESQUIRE,

OF GLASGOW,

These Remarks on Canal Navigation

ARE RESPECTFULLY INSCRIBED BY

THE AUTHOR.

REMARKS, &c.

SINCE the first formation of canals in this country, there have been very few attempts made, to improve the construction of vessels adapted to an inland navigation. The passage boats of the present day are nearly the same as they were fifty years ago; and little, or rather no improvement has taken place in the heavier description of vessels for the conveyance of goods, since the period of their first introduction. Probably this might have gone on in the same state of supposed perfection, had not the introduction of Railways, which are now in progress, occasioned such a sensation in the country.

From the first commencement of canal navigation up to the present time, the average speed of conveyance has never exceeded four miles and a half per hour on passage boats, and two miles and a half on heavy flats. This

seems to have been the maximum velocity; and it was taken as an established rule, that boats could not be conveyed along canals at a greater rate, without incurring loss, and a considerable increase in the cost of transit.

My particular attention was, in the month of January last, drawn to these very obvious defects in canal navigation, by Mr. Thomas Grahame, of Glasgow, who had, for some years before, been giving a great deal of attention to the improvements on canal navigation, by the introduction of Steam as a moving power.

At that period, Mr. Grahame had so far succeeded in drawing the attention of the managers of the Forth and Clyde Canal, and of the Union Canal to the superior advantage of steam-power, that the committee of each of these Companies had contracted for the construction of a steam boat, to ply on their respective canals, in that branch of business, which appeared most favourable for the introduction of steam-power in each. The boat, contracted for by the Forth and Clyde Canal, was on the American plan, with the paddle behind,—Mr. Grahame having procured a plan from New Orleans, of a boat of that description

plying on the river Mississippi. This boat was intended as a goods and luggage carrier-boat, to ply on the canal, and on the adjoining Firth of Forth, so as to extend, to the trade on the Firth, the advantage of the same regularity enjoyed by the trade on the canal.

The boat, contracted for by the Union Canal Company, was intended as a tug or drag boat; and was to be formed with the paddle in the centre, on the principle of the twin boat.

These boats were to be constructed by Mr. Neilson, Engineer, Old Basin, Glasgow; and although the second is not yet completed, the first has been for some time finished, and is at present plying on the Forth and Clyde Canal, and adjoining Firth of Forth. A plan and section of the boat is hereto appended; and an account of her action, both in the canal and Firth of Forth, will be hereafter given, when I come to enter on the detail and description of an improved goods and luggage-boat, with two stern paddles, which I have prepared for the Forth and Clyde Canal Company.

At the period above-mentioned, Mr. Grahame and myself had various discussions about the

introduction of steam-power, for the purpose of the conveyance of passengers along the canal, and to the various ports on the Firth of Forth, and also between the Firth of Forth and Clyde. We also had some communications with parties situated on the Firth of Forth, and interested in the passage and carriage between that Firth and Glasgow. The result of these communications was a decided opinion, on my part, that not only a regular, but a very speedy communication might be obtained by means of steam-power, with all these ports, provided the vessels could be built sufficiently light and spoon-shaped, like the boats, which Mr. Grahame informed me were used on the passage between New York and Albany, and which, it was asserted, could maintain a speed of nearly fifteen miles an hour. It appeared proper, however, that the Forth and Clyde Canal Company should complete the operations they had begun, of facing with stone the banks of their canal, and thus guard against all danger to the banks, from the introduction of quick velocities on that line of navigation.

Mr. Grahame requested me to give the subject my best consideration, in order to see how far such a light description of boat,

having a small draught of water, would be applicable to quick speed, and whether steam could not be advantageously used as a propelling power on canals.

The fulfilment of Mr. Grahame's instructions, was surrounded with difficulties of no ordinary character; such as, the resistance of fluids to moving bodies—the agitation of the surface, and the consequent danger to the banks of the canal, arising from the surge or wave, occasioned by vessels propelled at a quick rate. These, and many other obstacles presented themselves. Not the least, however, was the power requisite to raise, and maintain an accelerated velocity in bodies, opposed by such a powerful resistance. It also appeared questionable, whether the power required, was not more than commensurate to the advantage gained, by the proposed increase of speed.

In Holland the passage boats travel at the rate of six English miles per hour, and I believe on some lines of navigation, it is no uncommon occurrence, for boats to move even at a greater velocity. In this country we seldom, if ever, exceed five miles; and I am inclined to think, that four miles and a

half per hour, is the greatest and most advantageous speed we have yet attained.

The source to which I looked for improvements was steam; a judicious employment of which might remove the difficulties, and furnish power sufficient to overcome all obstructions. Steam engines of the usual construction, from their great weight, seemed but indifferently calculated for propelling boats on canals, as the draught of water would be increased, and greater risk of injury to the banks would be the consequence. Engines on the locomotive principle, from their portability and lightness, appeared best fitted for the purpose, and best calculated to give the requisite force, without materially increasing the weight of boat, or producing the apprehended injury to the canal banks.

This being a settled point, the next consideration was,—how to employ these engines to advantage;—how to give perfect security; and, at the same time, how to produce at least a double velocity, without incurring the injurious tendencies already detailed. This was certainly a desideratum more to be wished for, than expected. We all know, that force must be applied to a body to move it through a

fluid; that such force meets with opposition from the resisting fluid; and, that that resistance is stated to increase with the squares of the velocities. These points being taken for granted, it will be seen, that there was much to contend with, in surmounting such formidable obstacles.

Taking as a datum what has been already stated, that the resistance of fluids to passing bodies is as the squares of the velocities, I had then to calculate what power would be requisite, to give the increased speed to boats of different tonnage, and to produce a force equal to the resistance as laid down by scientific men, who have treated on this subject.

I was prevented pursuing with Mr. Grahame the inquiries on the subject of canal steam navigation by business, which compelled my own and his attendance in London, for the greatest part of last spring.

While we were engaged there, an experiment was made by William Houston, esquire, of Johnstone, on the Ardrossan canal; the results of which were communicated to me, and which at once seemed to make rapid

motion on a canal infinitely more easy, by doing away with the danger of injury to the banks, by wave or surge consequent on quick motion through a comparatively narrow body of water.

I knew him in 1842 JMB

The experiment, made by Mr. Houston, consisted in the introduction into the canal of a common gig boat, in which ten or twelve passengers were seated; after which, the boat was drawn through the canal by a single track horse, at the rate of twelve miles an hour, without either wave or surge. Unluckily no printed account of this experiment was ever published, or it would be proper here to insert it.

In pursuance of this first experiment, Mr. Grahame, on his return to Glasgow, proposed to have it renewed on the Forth and Clyde Canal; but on examining the gig boat, with which the experiment was made, he found it was so light and unsteady, as to give an idea of want of safety to passengers; and he was afraid that if a larger and stronger boat were built, it might have the same faults, and at all events it would be so crank, as to be unfitted for the application of steam-power.

To avoid these difficulties, and to obtain steadiness and security on the water, the idea of a twin boat of the description of the single gig boat, suggested itself to Mr. Grahame, and to prove the suggestion, an experiment was made, of which the following account appeared in the various newspapers of the day:—

"*Experiments on the Velocity of Light Boats on a Canal.*

"The following experiments prove, most satisfactorily, that a very high rate of speed may be obtained and kept up on canals for the conveyance of passengers and luggage, at a very trifling expense, and without injury to the banks, by the agitation of the water.

"About six weeks ago, at the suggestion of one of the committee of management of the Ardrossan Canal, a gig, such as is used in rowing matches, was hired, and being launched on that canal, it was found that she could be drawn along the canal, at the rate of twelve miles per hour. On this occasion, eight persons and the steersman were in the gig; when a distance of two miles was accomplished with one horse in ten minutes, without any surge or agitation of the water, so as to injure the banks.

"As, from the necessary lightness of the above description of boats, they are very crank or unsteady in the water, and easily moved from side to side, the following experiment, to try the effect of a double or twin

boat, was made on the Forth and Clyde Canal on Thursday last.

"Two gigs were hired, but unluckily two of the same size could not be procured. The one gig was thirty-three feet in length, and four feet two inches in breadth, at the broadest point. The other was thirty feet in length, and four feet in breadth, at the broadest. They were strongly fastened together by cross planks, and otherwise secured, so as to prevent any yielding. At the point in front, where the respective keels cut the water, the distance was exactly four feet nine inches, measuring along the surface of the water; while the distance about the centre of the boats, measuring on the surface of the water, was only 18 inches. Between the prows of the two boats, a pole was fixed or inserted in one of the connecting boards, three feet in height, and to the top of which a towing line was attached, which, unfortunately, however, was too short, and too thick. The horses also used for the trial, could not, except at a gallop, go at a pace above eight miles an hour. The boats proceeded from the old basin on the Forth and Clyde Canal, and went out three miles and a half towards Kirkintilloch. The first mile, including the passage of a bridge, where the line was thrown off, and the time lost in consequence of the rope yielding over the top of the pole, and being thus disengaged from the boat, was about seven minutes; and the surge was not greater, than that raised by the common canal passage boat. Even at the curves, where, from the shortness of the line, the boats were obliged to come close into shore, the water never receded under the bottom of the stone facing. The next two miles

were done, each in the course of six minutes, but the pace was very irregular, owing to the necessity of keeping the horse at a gallop. In returning the three miles and a half homewards, no regular account was kept of the first two miles and a half; but the last mile was done in five minutes, including the time lost at the passage of a drawbridge, where the line had to be thrown off; and the passing of a large sloop, where the speed was obliged to be slackened. In the last mile, the surge occasioned by the passage of the boat through the canal, was less than when moving at a lower velocity, and could not, by possibility, injure the banks in the least degree where lined with stone; nor would the surge have injured the banks more, though unlined with stone, than the ordinary passage boats moving a little upwards of five miles an hour. Mr. Hunter, the proprietor of the boats, stated his belief, that this would be the result of a high rate of speed before it was tried; but whether the decrease of wave arose from the steersman of the boats having become better acquainted with their trim in the canal, or from whatever other cause it arose, their effect was evident to every person on board. When passing through the water, there was very little agitation on the outside of the two boats; but the water was frequently raised six and seven inches, and more in the centre parts of the little trough or canal between the boats; so much so, that small portions of it were thrown over into the boats. The water, after passing the straight parts of the trough or canal between the boats, came out with great rapidity behind, and went off in a small column or wave, sometimes five or six inches above the keels or rudders, making towards the banks on each side. The number

of people on board the boats was nine or ten. After this experiment, the larger boat was detached, and two miles out and in on the canal, were done at the rate of fifteen miles an hour. One of these miles, where a bridge had to be passed, and in which a loaded vessel was also passed, and where at the bridge the line had to be thrown off, and then caught and thrown into the boat, was done in four minutes and a half. In fact the speed seemed only limited by the power of the horses. The surf or surge was very slight with the single boats, even when moving at fifteen miles an hour; but still it bore a much greater proportion to that occasioned by the double boat, considering the very unfair nature of the trial, than could have been imagined. No danger is to be apprehended from the stoppage of the double or single boats, however suddenly, as they brought themselves up almost instantaneously. It is right to explain, in regard to the trial of the single boat, that this trial was made with the same horse that had previously done the experiment in the double boat; otherwise the time would, no doubt, have been considerably shorter. One horse only was used in drawing, and for the first two or three miles, it was ridden by the driver, a heavy man, without a saddle.

"There can be no doubt, that if the above experiment had been made with a properly constructed twin boat, the surge or wave must have been much diminished, if not entirely done away with; while the boat would have been equally steady. We understand that a large passage boat, of a gig-shape, is at present constructing by Mr. Wood, of Port-Glasgow, for the Ardrossan Canal; and that it is expected she will per-

form the voyage between Paisley and Glasgow in three quarters of an hour, carrying 36 passengers. As this boat is to be single, it has been suggested that any unsteadiness or crankness in the water may be done away with, by placing around the boat, and a little above the water mark, a hollow copper or iron tube, such as is used in safety boats. In this way she would at once be brought to a bearing, before yielding much to either side, and at the same time the boat would be at once made a safety boat.

"Three different results from the above experiment are worthy attention: first, the ease with which the boats were brought up or stopped, when moving at a high rate of velocity; second, the little additional labour in drawing, occasioned to the horse when drawing the boat at this high rate, as compared with a low rate of velocity; and third, the apparent diminution of the surge or agitation in the water, at a high rate of velocity. The best explanation of these matters is by the supposition, that at a high rate of velocity, the flat boat rises toward the surface, and skims over instead of cutting the water. The moment the towing line is slacked off, the boat sinks to her usual depth, and of course brings herself up immediately, owing to the increased resistance of the additional column of water, which she must cut. On the other hand, when moving at a high rate, and skimming near the surface of the water, the labour of the horse is diminished in proportion to the diminution of the column of water displaced, and the wave or surge is diminished in a like ratio. The Ardrossan Canal is a very small barge canal, fitted for boats of from 25 to 30 tons burthen;

while the Forth and Clyde Canal is ten feet deep, and of a proportional breadth. The gigs, with which the above experiments were made, belonged to Mr. Hunter, boat builder, Brown-Street, Glasgow, who fitted up the twin boats for the experiments in the Forth and Clyde Canal; and who is, at present, engaged in making the model of a large twin boat, fitted to carry passengers and luggage on the Forth and Clyde Canal. Great credit was due to Mr. Hunter, for the mode in which the twin boat was fitted up and connected."

The diminution of wave or surge consequent on very rapid motion through the canal, stated to have been observed by Mr. Grahame, the writer of the above account, appeared very anomalous and contrary to all previous theory; and was, by many persons present at the experiment, considered as *ideal.*

In the month of June afterwards, in consequence of the success of Mr. Houstoun's experiment, a light gig-shaped boat, built by the Ardrossan Canal Company, was launched on that canal, and the following is a detailed account of her first voyage, to and from Paisley:—

"*First Voyage of the Paisley Canal New Passage Boat.*

"Some months ago, by the suggestion of Mr. William Houstoun, of Johnstone, the Committee of Management

of the Ardrossan and Paisley Canal, were induced to make certain experiments, for ascertaining the rate of velocity, at which a light gig boat might be propelled along that canal. The experiments were made with a gig rowing boat of about thirty feet in length, constructed by Mr. Hunter, boat builder, Brown-street, Glasgow; and this boat, with ten men on board, was drawn two miles along the Ardrossan or Paisley Canal, in the space of less than ten minutes, without raising any surge or commotion on the water—the force employed being one horse, ridden by a canal driver. No account of this trial has ever been given to the public; but it was so satisfactory, as to induce the committee of the Ardrossan Canal to contract with Mr. Wood, of Port Glasgow, for a gig-shaped passage boat, sixty feet in length, and five feet in breadth, fitted to carry from thirty-six to forty passengers.

"In the month of April last, a number of experiments were made in the Forth and Clyde Canal with two gig boats fixed together, constructed by Mr. Hunter, and thus forming, what is called, a twin boat. The object of these trials was to ascertain the rate of speed, at which vessels might be propelled along that canal; and the effect of a light double or twin boat, in giving that degree of steadiness, which, it was apprehended, would be so much wanting in a light single boat. A statement of these experiments on the Forth and Clyde Canal, has already appeared in the newspapers, and the only fact therein mentioned, which it seems necessary to repeat here, is the remarkable circumstance, that the quicker the boats were propelled through the water, the less appearance there was of surge or wave on the sides of the

canal. This result, so contrary to every previous theory, was doubted by several of the parties present at these experiments. The surge was, at no time, and in no instance to any extent; and the apparent diminution of it at a high rate of velocity, was supposed to be imaginary. The result of the experiment, however, was so satisfactory, that a twin boat of a gig shape, sixty feet in length, and nine feet broad, is at present building by Mr. Hunter, Brown-street, Glasgow, and will be launched in the Forth and Clyde Canal, in the course of the present month.

"The single gig-shaped passage boat, contracted for by the Ardrossan Canal Committee, was launched at Port Glasgow on Wednesday last, the 2d of June, and she was towed up to the Broomielaw, and thence carried to Port Eglinton the day following; and on Friday, the 4th of June, a trial, of which the following is an account, took place. The boat is sixty feet long, four feet six inches breadth of beam, and drew on an average, including a deep keel, ten inches when light.

"From the great hurry in which this trial was made, it was done under many disadvantages. None of the canal horses were accustomed to, or able for a continuation to move at any high rate of speed, and a post horse which had never towed a boat, and was quite new to the kind of work or pull necessary on a canal, was the substitute. The hauling rope was too thick. The boat started from Port Eglinton for Paisley a few minutes after one o'clock, with twenty persons on board; and the distance from Port Eglinton to Paisley, being seven miles, was accomplished in one hour and seven minutes. The

greatest speed, with which the boat moved during this journey, was at the rate of one mile in nine minutes; and the slowest rate, at which any one mile was accomplished, was eleven minutes.

"As the horse was quite unaccustomed to dragging boats, and it was apprehended that it might scare at the canal, and in passing under the narrow bridges, the rider was ordered to start, and proceed the first mile or so at a very moderate pace; but even at this moderate pace the wave raised in front of the boat was very considerable. A high wave was seen on the canal preceding the boat, about eighty or ninety feet in front, and in some cases farther, and causing an over-flow at the bridges, and in the narrow parts of the canal. The surge or cutting wave behind the boat was, however, comparatively slight, and except at the curves, would not have caused much injury to the canal banks. The horse was very much exhausted when he got to Paisley; though by no means so exhausted as he was about the middle of the journey, having sensibly recovered after the first four or five miles.

"As it would have detained the party who came to witness the trial too long, if they had remained at Paisley till the horse was fed, two post horses were hired there; and lighter towing lines being attached to the boat, it started again, on its return to Glasgow, with twenty-four persons on board, four of whom were boys, and arrived at Glasgow, a distance of seven miles, in forty-five minutes. Unluckily, one of the horses, the front one, scared very much at the canal, and at the bridges; and two or three stoppages took place in con-

sequence of this horse getting entangled with the ropes. By altering the mode of attaching the rope, and putting the second horse in front, this difficulty was partially got over; and the distance of seven miles was accomplished in forty-five minutes, including in these forty-five minutes the time occupied in disentangling the horses, and changing their positions, and the constant delay occasioned by the horse before-mentioned scaring at the canal. The greatest speed attained during the journey was two miles in eleven minutes. During this voyage the surge behind was entirely got quit of, even at the curves, where it was reduced to nothing; and there was no front wave, except at the bridges. It appeared only at the bridges, and just as the boat was about to enter under the bridge, and gradually disappeared as the stern of the boat cleared the bridge. The quicker the boat went, the more entire was the disappearance of all wave and surge, except where the water escaped in the centre of the canal, and met in two very noisy and rapid currents from each side of the boat at the rudder. This noise and rush of water was so great behind, as to induce persons on board to look round, expecting to see a great wave or surge on the bank of the canal, but on the banks there was hardly a ripple. The two rapid noisy currents seemed to be completely spent and exhausted, by the shock of their concourse behind the boat. Here, therefore, there was no room to doubt of the correctness of the reports of the Forth and Clyde Canal experiments. It was not merely to be said that the greater the speed the less the surge or wave, but it was demonstrated that at a high rate of speed surge and wave were done away with altogether.

"Although, according to all established theory and calculation as to the force requisite to obtain accelerated speed on water, the two horses from Paisley did more than triple the work of the single horse from Glasgow, supposing they had worked together, while it was evident that almost the whole work was done by one of the two, yet they were both much less fatigued than the single horse. Unluckily, there was no Dynamometer attached to the rope, so as to ascertain whether, contrary to all theory, the strain or pull was not equally diminished with the wave, and the tugging labour of the two horses lessened instead of increased, by the accelerated rate at which they drew the boat. There can be no doubt, however, that with one trained horse, properly attached, the distance could be done in a period under forty minutes.

"Contrary to expectation, Mr. Wood's boat was quite steady in the water, and by no means crank. When in the basin at Paisley, seven full grown persons stood on one side of her while she was empty; and could not, with their united weight, bring down that side to within some inches of the water. The keel was, however, very deep and heavy, and is to be altered.

"It may be proper to mention that the Ardrossan Canal is throughout very narrow; at the bridges and many other places it is only nine feet broad. It has a great number of turns, and many of them very sudden."

This voyage, at once, set at rest all doubts on the subject of the effect of a high velocity,

with a gig-shaped boat in a canal; and the boat in question has since been regularly plying on the Ardrossan Canal, carrying from forty to fifty passengers, between Glasgow, Paisley and Johnston; and has fulfilled all the anticipations of the parties, for whom she was constructed.

From the above it will be seen that the question of surge and injury to the banks, so much feared, and so strenuously insisted upon by the parties opposed to improvement, was for ever set at rest, by the voyage made by the light gig boat, in one of the narrowest canals in Scotland.

The trial of the Paisley boat was speedily followed by a second trial on the Forth and Clyde and Union Canals of a twin boat built for Mr. Grahame, by Mr. Hunter, of Glasgow, to prove, on a large scale, the practicability and advantages of twin boats for canal navigation.

The boat, built by Mr. Hunter, being launched, an experimental voyage was made to and from Edinburgh; at this voyage I was present, at the request of the committee of management of the Forth and Clyde Canal,

in order to give an opinion, as to the practicability of the application of steam-power to propel with rapidity a boat of the twin form. The following is an accurate account of this experimental voyage.

"*Improvement on Canal Navigation.—First voyage of the New Passage Boat Swift, from Glasgow to Edinburgh, and back again.*

"The Swift is sixty feet long, and eight feet six inches broad, twin built, and is fitted to carry from fifty to sixty passengers.

"On Wednesday the seventh of July, she started from Port Dundas at sixteen minutes past nine in the morning, having on board thirty-three passengers, (all men) with their luggage. Proceeding through the Forth and Clyde Canal and Union Canal, she reached Edinburgh at twenty nine minutes past four, in the afternoon. She thus made a voyage of fifty six miles and a half, in the space of seven hours and fourteen minutes. In the course of this voyage, she passed through 15 locks, 18 drawbridges, a tunnel 750 yards long, and over three long narrow Aqueduct bridges, and under sixty common bridges, which carry roads over the Union Canal. Her average rate of speed during the voyage, was nearly 8 miles per hour, including every stoppage.

"On the following day, viz. Thursday the 8th of July, the Swift started from Edinburgh 22 minutes past nine in the morning; and returning by the same route with thirty three passengers (all men,) and lug-

gage, she reached Glasgow precisely at four o'clock in the afternoon, that is, in six hours and thirty eight minutes; going thus at the rate of nearly nine miles per hour.

"On both days the weather was most unfavourable from much rain, and a strong gale of wind directly in her face—the wind having been from the East on Wednesday, and from the West on Thursday.

"When free from the locks, tunnel, and other impediments, the speed, at which she proceeded, varied from six miles to twelve miles an hour; and the extraordinary results of the previous experiments, made on the Paisley Canal, and Forth and Clyde Canal, were again completely verified and ascertained, during her progress through, one hundred and thirteen miles of canal navigation. For it appeared that when she moved through the water, at the rate of six or seven miles per hour, there was a great swell or wave constantly in her front, and she was followed by a strong surge or wave, bearing against the bank of the canal. At these times the hauling rope was tight, and the horses appeared to be distressed. But as the speed was increased, the wave or swelling of water in her front sunk down; and when the speed came to be about nine miles per hour, the swell entirely disappeared; the waters in her front became smooth and level; the hauling rope slackened; and the horses seemed easy, and little or no surge was to be seen on the banks behind the vessel.

"There appears, therefore, no reason to fear, that the banks of canals can ever be hurt, by increasing

the speed of boats to the utmost attainable height; and measures are in progress for increasing the speed of passage boats on the Forth and Clyde Canal, and Union Canal; or, at least, of keeping it during the whole voyage between Glasgow and Edinburgh to the highest rate, which has been already realized, and thus reducing the whole length of the time consumed in the voyage to five hours.

"Experiments are at present making to ascertain the exact force of weight or pull necessary to propel or drag the Swift, when loaded or unloaded, at various rates of speed, from one mile up to twelve or thirteen miles per hour, the results of which will be hereafter given to the public. These results will, it is anticipated, overturn the present established theories on this subject; and will prove how very little additional force is necessary to propel a vessel, at a high rate of velocity, through a broad, and through a narrow canal."

The facts detailed in the preceding article seem to establish the principle,—that the greater the speed the less the surge; and that a gig-shaped boat, moving at a velocity of nine miles per hour, completely surmounted the surge, and rode over the accumulating swell, that otherwise would have risen in her front.

It is a curious, yet important fact, that a gig-shaped boat, moving at a velocity of from

seven to eight miles an hour, produces a considerable swell running longitudinally with the canal, and by the displacement of water, forms a hollow trough, with a heavy surge fore and aft of the boat, rolling sluggishly along the banks, and in many cases washing over the track path, ten or twelve inches deep. Produce however an impulse equal to nine miles an hour, or until the boat is impelled at a velocity greater than the undulating motion of the water, and immediately the swell disappears; the boat glides smoothly along the surface, and proceeds with as much apparent ease, as if she were moving at only four or five miles an hour.

After these trials, which were made in the presence of certain members of the Forth and Clyde Canal Committee, I arranged a variety of experiments, for the purpose of ascertaining the force expended in moving forward the twin-boat, at various rates of speed, and with various weights; and also, the effect of the application of side and centre paddles, worked by men placed in the twin-boat. These experiments are detailed and described in an annexed appendix; to which is added an engraved figure of the twin-boat Swift. The result of these experiments shewed,

that the resistance to a body, drawn along a line of water confined within the banks of a canal, did not appear to increase in the ratio laid down in theory, and that while at a low rate of velocity, viz. at and under six miles an hour, the resistance to the progress of the boat, on a broad line of water, was considerably less than on a narrower line; on the contrary, at a high rate of velocity, say above ten miles an hour, the forces necessary to the propulsion of the boat on a broad and narrow line of water, appeared to be the same, if the advantage was not rather in favour of the narrow line.

The results were such, as to induce me to recommend, and the Forth and Clyde Canal Committee to agree, to build a light twin iron steam passage boat, to ply between Glasgow and Edinburgh. The Canal Committee intrusted me with the construction of this boat, and the application of the steam-power; and gave me the valuable assistance of Mr. Hunter, to form the model and water lines of the new boat.

The business I had now in hand was to ascertain, how, and at what cost, the object which I recommended the Forth and Clyde Canal

Committee to pursue, could be attained. It was not an abstract question of practicability, but how far a very high rate of velocity could be *advantageously obtained*; at what cost, and what might be the comparative difference of expense, between the proposed new principle, and the present mode of trackage. These were questions, which very naturally presented themselves in the discussion of this subject; it was clear and evident to all parties, that a double rate of velocity, coupled with the retardation and resistance, to which bodies impelled with such rapidity of motion were subject, must be obtained at a considerable increase of cost, though by no means so great as had been previously anticipated. At a slow rate of travelling, when time is not an object, and the arrival and departure of vessels are not calculated upon, beyond a rate of two miles and a half, or four miles and a half an hour, horses are then comparatively well adapted for the purpose; but when despatch is wanted, and where a voyage must be performed within a given time, then, steam-power and a quick rate of travelling are the only alternative; and from the experiments already made, I entertain little doubt of success in this object.

In pursuit of this view, a twin steam boat has

been designed, and is now nearly completed, of which a correct plan and section is represented in the title-page of this publication. The following are her dimensions:—

Whole length, 68 feet.

Breadth on beam, 11 feet 6 inches.

Depth, 4 feet 6 inches.

Width of tunnel or wheel-trough, 3 feet 10 inches. This wheel-trough extends longitudinally down the middle of the boat;—it is made wider at each end, in order to facilitate the supply and escapement of water from the paddle wheel.

Depth of tunnel, 3 feet 6 inches.

Steam engine, 10 horses' power, which it is intended shall give from 50 to 60 strokes, or thereabouts, per minute.

Diameter of paddle wheel, 9 feet.

Whole weight, including engine, paddle-wheel, &c. 7 tons 16 cwt.

Draft of water, 16 inches.

This boat will be finished early in January, 1831, and will commence plying on the Forth and Clyde Canal in the following month. She will accommodate from 100 to 150 passengers, according to the kind of accommodation desired by the Canal Company.

How far this boat will realize my own views, and those of the Forth and Clyde Canal Com-

pany, time, *and a very short time*, must decide. For my own part I have little doubt of her entire success, so far as velocity is concerned; and as to cheapness, I have no doubt, that on such navigations as the Forth and Clyde and Union Canals, where coal is abundant and cheap, it will be found the least expensive and most eligible mode of conveyance. With the velocity, I anticipate from nine to ten miles an hour, the cost to the Canal Company for the conveyance of a passenger, between Edinburgh and Glasgow, fifty-six miles, will not much exceed two-pence; which is not a fifteenth of the expense of the conveyance of the same person, at the same rate, supposing it attainable and maintainable, by horses.

I have given the fullest attention to the construction of the machinery, in order to make it answer the views and hopes of my employers, and myself; if I fail, I trust that the present attempt will be followed, by others more successful.

I might have delayed this publication till the twin boat was fairly launched and tried, but it has been urged, that such delay would have argued distrust in what has been planned and done. This I am anxious to avoid, as I have

entire confidence in the recommendation I gave to the Canal Proprietors, and however I may have failed, in the details necessary to carry the measure recommended into execution, I am confident that the ends in view are perfectly attainable.

Having thus mentioned the peculiar adaptation of the twin boat to high speed, and to the conveyance of passengers, I shall now give the reasons, why, a boat constructed with a stern paddle seems best fitted to succeed in a voyage, where the boat, carrying goods and luggage, has to pass from a canal into the open sea, or *vice versa.*

It is quite clear, that, whatever may be the comparative merit of side paddles, such paddles are out of the question in canal navigation; as, independent of their liability to be injured in the locks, and on the banks of the canal, they must contract the bearings of the vessels to which they are attached, and make them of very small burthen. The centre paddle or twin boat principle, in like manner, contracts the bearings of the vessel, and the tunnel in which it works is liable to be choked, whenever the vessel moves from the canal into the sea, in stormy weather.

The stern paddle seems, therefore, the only means for adapting a canal steam boat, both for sea voyages and canal traffic. The Cyclops Steamer, formerly mentioned as built for the use of the Forth and Clyde Canal Company, fully confirms this conclusion, and also points out, what improvements may be made on boats of this description. I shall here give an account of her first voyage to Alloa, as contained in a letter from Mr. Grahame to myself, in the month of October last:

" *Glasgow, 7th October*, 1830.

" MY DEAR SIR,

" Since I wrote you last, I have been on the Firth of Forth and through our canal in Mr. Nelson's boat, with the paddle behind; and the results of this voyage have been most satisfactory. The boat, except as regards shape, is replete with errors. She is too heavy; viz. she bears about with her a quantity of iron, sufficient to build nearly two boats of the same size, and of equal strength. Her engine, which ought to have been high pressure, is low pressure, and, though a sweet-going machine, is much too heavy. Her paddle, which from its position must necessarily labour under the disadvantage of a deficient supply of water, is so placed as to enjoy this disadvantage to its greatest possible extent, and, in addition, a considerable portion of the broken water, coming from the paddle, strikes on the stern-iron of the boat and retards her progress. I could state a

number of other faults, but will not trouble you with them. The party most opposed to stern paddles could not have desired a trial, where every possible disadvantage was more decidedly experienced. With all these disadvantages, and taking them to be irremediable, I am decidedly of opinion, that, in all cases where the breadth of a boat is limited, or where the paddles are subjected to risk of damage from narrow banks, &c. stern paddle-boats will be introduced, as best adapted for boats intended to carry large cargoes of goods, at a moderate velocity If all that is wanted is *despatch*, or *the slow or moderate trackage of vessels* THROUGH A CANAL, the stern paddle may not answer so well, as side or centre paddles; but if a boat is wanted, which will carry a large cargo, and move, both in a canal, river, or at sea, with a moderate velocity, then the stern paddle is the right means.

"We have already ascertained, that the Cyclops can move through the canal with twenty tons of cargo, at a rate of about four miles and a quarter per hour, or rather better; and that, even with this loading, she can drag another vessel behind her, without any considerable diminution of her speed. Every person on board the Cyclops, when the above facts were ascertained, was convinced that an increase of the cargo to thirty-five or forty tons would not have affected her speed. In fact, it appears as difficult to lessen her speed as to increase it. When her engine makes twenty-five and thirty-three strokes in the minute, her velocity in the canal is about the same; while without any addition to the number of strokes, her velocity was increased nearly one-half, when

in the Firth of Forth. This clearly shews that the deficiency in speed arises from a defective supply of water.

"But, to return to our experimental voyage:—We started from Grangemouth for Alloa, after breakfast on Tuesday the 29th of September. The distance is said to be ten miles, and cannot be under nine miles. We had the tide against us for the first two miles, going out of the Carron river, and for the last mile or so going up to Alloa, and we accomplished the distance in one hour and forty minutes, including a stoppage of some minutes for a small row boat that hailed us. We returned with a favourable tide in the Forth, but strongly against us in the Carron, in an hour and a half. The Cyclops in these two voyages was much by the stern, being without a cargo. We had intended to take in twenty or thirty tons of coal at Alloa, but could not get them. There was a very strong side wind on the Forth, and the Cyclops proved herself a most steady, excellent sea-boat, and steered most beautifully. She appeared to me to steer far better than a side paddle boat, and the men on board said she could turn almost in her own length. When we brought her into the canal, we attached her to the passage boat, and she drew her along the canal two miles—one mile in fourteen, and the other in fifteen minutes. We then detached her from the passage boat, and did two other miles, but could not save, by this decrease of her labour, more than a minute, or a minute and a few seconds in each mile. She was then attached to the passage boat, and dragged her on to Port Dundas. The whole time consumed on the voyage from Alloa to Port Dundas, a distance of forty

miles, including the passage of twenty locks, by the Cyclops, and four by the passage boat, a considerable time lost at Grangemouth, making some inspections, and several other delays, and a long stop at the entrance of the Union Canal, was something under ten hours and a half; and if the Cyclops had been properly loaded with a cargo of twenty or thirty tons, the voyage would have been accomplished in less time, with all the delays and the trackage of the passage boat. The estimate of Mr. Johnstone, who is to have the management of the Cyclops, and myself, is, that with a cargo of from forty to fifty tons, she will do the voyage to Alloa, even against a head wind, in eight hours and a half; and I do not think this period would be much increased, except by delay at locks, though the Cyclops, in addition, towed another vessel the whole way. I am also much inclined to think that she will make her way against a head wind, much better than a side paddle boat; and that, contrary to the American statement as to stern paddle boats, she will do better than any other kind of steam boat at sea; but this does not bear on the subject of steam-carrier boats intended for sea and canal navigation, as to which I am now writing, where breadth of beam or bearing cannot be attained with side paddles. In canals, stern paddles for goods boats must be applied, if these boats are intended to go to sea; and, from the experiments already made with the Cyclops, I am certain the application must be successful. I am also convinced that a boat exactly similar to the Cyclops may be built, which will carry a larger cargo, and move at a much higher velocity with the same power. The first improvement is in the use of lighter iron; the second improvement is

the substitution of a high pressure for a low pressure engine, and the cutting away all the iron work which obstructs the escape of the broken water. This last alteration would balance the boat a great deal better. The next improvements are by no means so certain or assured as the two last-mentioned, and consist in an alteration of the position of the paddle and of the build behind, so as to obtain a better supply of water for the paddle to act on. To understand these improvements, I beg leave to refer to the accompanying sketch of the Cyclops. From this sketch it will appear, that the paddle works in a box supplied with water from the front, sides, and stern of the boat. The supply from the front and sides of the box must come in, under the bottom of the boat; and to facilitate the supply from the front, the centre keel or bottom of the boat is made to ascend a little to the front of the wheel, so as to let the water from the bottom of the boat get easier into the box or tunnel. The water which supplies the wheel, except the portion coming in from the stern, is in a manner pumped up by the wheel from under the bottom of the boat, and there is evidently a constant want of supply, as the water in the inside box is always lower than on the outside. The first improvement, that would suggest itself to any one, would be the removal of the paddle nearer to the stern of the boat or outer end of the box, so as to make the supply of water from the bottom of the boat more firm, unbroken and regular, than it can be at that part of the box, where the paddle is now situated. To this improvement it may be objected, that such removal would not only make the boat hang more by the stern, but would cause a lengthening of the

connecting rod which moves the paddle, and a consequent loss of power. So far as this objection is founded on the additional stern weight, it may be got quit of by the application of a high pressure engine. The weight saved by this application would much more than counterbalance the additional lever power given to the paddle. At all events, if the paddle is not at the end of the box, *the box should end* where the paddle ends, or a small portion of the paddle might even be left out. The next improvement would be the giving of a supply of water to the box and paddles, by two large pipes passing angularly from the side of the boat into the front part of the box. This would occasion a certain additional resistance to the progress of the vessel, and the question here to be determined is, whether this additional resistance would counterbalance the effect of the additional supply of water to the wheel. The last improvement, and which is one that occurred to myself, would be to cut away the two lower sides of the boxes on each side of the paddle, so as to give a perfectly free admission of the water to the wheel. To this again it is objected that you lose a considerable portion of the stern bearing of the boat, and that you also require this bearing, and the strength of the iron cut away to support the paddles. I should think the weight saved by the high pressure engine would more than counterbalance the loss of bearing; and at all events, I think the side boxes might be partially cut away at the bottom and end, so as to allow the supply of water to come more easily and plentifully; and I am rather inclined to think this is the proper improvement, as by sinking the side

boxes in the water a little, they will act as a more effectual protection to the paddles against side wave and wind at sea. All that is wanted for the stern paddle is to give it an additional supply of water, and if such additional supply can be obtained, I think these boats will in time supersede the use of side paddle boats, even as of passenger boats. In the mean time I think as goods and luggage boats, more especially where breadth of beam is wanted, and where it would be contracted by the use of side paddles, they are the best. In the case of the Union Canal, for instance, where the locks are only twelve feet broad, and where it would be very desirable to have a steam communication direct from Edinburgh to Greenock, this can easily be attained by a stern paddle boat. The boat might be nearly twelve feet beam, and by building her of lighter iron, and using a high pressure engine, she might be made to carry nearly as much as the Cyclops on the same draught of water. This is also the kind of boat which the Mersey and Irwell Company should get for their goods trade. She could act as a dragger when required, and would herself do more business, than three, four, or five of their lighters.

"I have written to the Union Canal Committee on this subject, and wish them to employ you to prepare for them a plan and specification of a stern paddle boat, and in the mean time trouble you with this information."

Since the foregoing letter was written, the Cyclops has been regularly trading between

Glasgow and Alloa, and has made her voyages to and from that place, during several of the most stormy days of this winter; leaving Grangemouth on her voyage to Alloa, when no sailing vessel could venture out. She has carried in these voyages a cargo at one time of forty tons, and performs the voyage from Alloa to Port Dundas, in little more than half the time which is consumed in tracking a vessel, of the same burden, from Grangemouth to Port Dundas, about two-thirds of the distance. Every person must be struck with the great power of burden of this vessel (the Cyclops) on a small draught of water, and I question much if there be a steam-boat in the kingdom which, on a draught of almost double that of the Cyclops, can carry such a cargo. One of the great objections stated by Mr. Grahame to this boat in his letter to me, is the weight occasioned by the unnecessary thickness of the iron side plates, but this was unavoidable, as the Cyclops was constructed, or rather altered, from an old passage boat belonging to the Canal Company, where these thick plates were used, and this thickness of plate it was impossible to alter, unless the boat had been entirely rebuilt.

Having been consulted by the Forth and Clyde Canal Company, as to the improvements

suggested by Mr. Grahame on the Cyclops, I have inspected her, and made a voyage with her to Alloa. After due consideration, I am convinced that all the objections to the build of the Cyclops may be got over, and that by a change in the position of the paddle, a much greater improvement may be made in the powers and capabilities of stern paddle vessels, than is at present anticipated.

The improvements I suggest would be, to construct a vessel with two narrow paddles on each side, close to the rudder or stern of the vessel; this would in a great measure obviate the objections urged against the Cyclops; it would remove every impediment to the free access of the water to the paddles, and allow a free and open outlet to the discharge of the wheels on each side: it would also give considerably more bearing to the stern of the vessel; facilitate the working of the rudder; and furnish a large useful hold, instead of two comparatively small ones. It may here be urged that two paddle wheels, viz. one on each side at the stern, would be liable to get damaged against the locks, bridges, and banks of the canal: this is certainly an objection of some weight, but, on a minute inspection of the plan, it will be found that a remedy is

provided by a fender, or Portcullis, sliding down on the outside of the wheels to protect them from injury during the time they are passing the canal: at other times, when the vessel is in the open sea, the Portcullis is drawn up, leaving the whole space open for the free action of the paddles.

I am quite persuaded that this change will tend to assimilate, as much as possible, the navigation of the sea, rivers, and canals, and will have no effect on the surge occasioned by the motion of the vessel through the water: in fact, I am rather inclined to think it will have a tendency to neutralize the surge, and produce no other agitation than a rippling wave in the centre of the canal. I think the change must also greatly improve the speed of the vessel, but, to what amount, it is impossible to say without trial. A plan of the new proposed steamer is annexed to this publication, with the other plates.

It may be asked whether steam navigation is applicable to, or would pay on canals not communicating with the sea. The experiment of the Cyclops has completely proved the benefit of steam navigation, in a canal connected with a firth or arm of the sea. In

this case, greater speed is acquired, both in the canal and at sea, than could be got by any other kind of boat; and, in addition, perfect regularity is insured after the steamer leaves the canal; or, in short,—the firth or arm of the sea connected with the canal, and even the sea itself, are turned into a portion of inland navigation, so far as respects regularity.

In a canal, however, not communicating with the sea, steam-power must be equally efficacious, although in its general application it may not be productive of the same advantages, as on those canals having a free outlet to the sea; as, in the latter instance, vessels have the opportunity of extending their voyages to the adjoining Ports on the Coast.

However much I was persuaded that steam-power was the cheapest for high velocities, and also, for propelling vessels on canals where the trade was regular, I was not till lately prepared to consider a steam boat, on a canal, as the cheapest for the conveyance of goods where the trade was irregular, and where the boat had not only to contain a cargo, but at the same time had to carry her own engine, and all the conveniencies necessary for the application of machinery.

Mr. Grahame has lately put into my hands a letter on this subject, addressed to a shipping company carrying goods along a line of canal fifty-six miles in length: the calculations contained in that communication are given in the appendix, and seem to be decisive in favour of steam-power.

The company to which this letter is addressed, have to pay for a quantity of horse-power sufficient to deliver forty tons of goods at each extremity of the line of fifty-six miles every day in the year, besides a spare power employed chiefly in one particular branch of their trade. The sum they pay for each delivery is one guinea each way, *or at a rate of about one-ninth of a penny per ton per mile for the trackage of the goods conveyed.* The company in question supply the tracking lines, but with this addition the charge for trackage is not increased to *one-eighth of a penny per ton per mile.*

This is certainly a small sum whereon to effect a saving by a change of power; but, nevertheless, it appears (from Mr. Grahame's and my own calculations) that not only such saving may be effected, but an additional saving of a large portion of time can be made.

by the change from horse to steam-power. Having said this much, I will refer the reader to the calculations printed in the appendix, in order that he may draw his own conclusions as to the accuracy of those statements.

The calculations here referred to make it quite unnecessary to say anything on the subject of steam-power as a substitute for trackage on canals. If it be so much cheaper than horses in the expensive shape of a moving and carrying power, united in the same boat, what advantages may not all canals derive from its introduction in the cheap form of a tug-boat, in place of horses?

I should here observe, that, the application of steam, either as a propelling or tracking power on canals, will, on most navigations, require a regular system of management. Certainty and despatch are the very sinews of commerce. Every facility should, therefore, be given to the arrival and departure of vessels, to insure the confidence of traders, and perfect certainty that goods will be received and delivered at their respective destinations, at proper and stated intervals. I conceive this to be a principle of management imperative on canal and all other companies, as nothing conduces more to

the well-being of trading establishments than good regulations, founded on celerity and despatch in the traffic.

GENERAL OBSERVATIONS.

The immense value of canal property, and the great extent of inland navigation throughout the various districts of Great Britain and Ireland, fully establish the fact, that much has been, and much may yet be done, to give extended facilities to the trading interests of the country. It has already been observed, that nothing contributes more to encourage the industry of an active population than a steady, regular, and well-timed delivery of the minerals and various manufactured articles of the country; that a saving of time is of paramount importance, and, united to a well-organised system of management, would give cheapness, certainty, and despatch to all the operations connected with the transport of goods.

That the present system of canal navigation is defective, admits of little doubt; and we have only to refer to the traders on most canals, to know that much time is lost, and great uncertainty produced by the delays occasioned by drivers, boatmen, and others en-

gaged in the working of the boats from one destination to another. Under the very best system, as things now are, heavy boats or flats are dragged along canals at a very slow speed; and that slowness, itself, points out the necessity of improvements, such as are contemplated in the experiments referred to in the narrative. Although these experiments were confined to the Forth and Clyde, Union, Monkland, and Ardrossan Canals, yet they are, nevertheless, applicable to all other navigations of a similar character,—such, for instance, as those enumerated in the annexed list, shewing what canals are best adapted to steam boats for the carriage of goods, and for quick light boats for the conveyance of passengers.

TABLE OF CANALS, &c.

Calculated for the Admission of the larger description of Vessels.

	Sizes of the largest vessels which the locks will admit. Length. FT.	IN.	Width. FT.	IN.
Air and Calder Navigation	53	0	14	2
Avon Navigation	82	0	15	6
Barnsley Canal	53	0	14	3
Bolton and Bury Canal	68	0	15	0
Bridgewater Canal	73	0	14	2
Calder and Hebble Navigation	53	0	14	2
Chester Canal	64	0	14	7
Cromford Canal to Butterly Tunnel	72	6	14	6
Dearne and Dove Canal	53	0	14	4
Derby Canal and Extensions	72	6	14	6
Douglas Navigation	66	0	15	0
Droitwich Canal	64	0	14	0
Dunn Navigation	53	0	15	2
Ellesmere Canal	64	0	14	7
Erewash Canal	72	6	14	6
Gloucester and Berkeley Canal—Ship	163	0	29	6
Do. do. do. Barge	115	0	29	6
Do. do. do. Trow or Boat	81	6	13	6
Grand Trunk Canal, from Shardlow to Horninglow	72	6	14	6
Grantham Canal	72	6	14	6
Lancaster Canal—Glascon Dock Locks	72	0	14	6
Lancaster Canal—Johnson's Hill Locks	66	0	15	2
Leeds and Liverpool Canal, from Liverpool to Wigan	76	0	15	2
Leeds and Liverpool, from Leeds to Wigan	66	0	15	2
Leicester Navigation	70	0	14	6
Lydney Canal	110	0	25	0
Melton Mowbray Navigation	70	0	14	6
Mersey and Irwell Navigation	66	0	15	6
Nottingham Canal	72	6	14	6
Nutbrook Canal	72	6	14	6
Oakham Canal	72	6	14	6
Ramsden's Canal	53	0	14	2
Rochdale Canal	73	0	14	2
Sankey Navigation	65	0	16	9
Sheffield Canal	53	0	15	2
Soar Navigation and Loughborough Canal	70	0	14	6
Stroud Canal	72	0	17	6
Thames and Severn Canal, from Stroud to Brimscomb Port	72	0	17	6
Do. from Brimscomb Port to Inglesham	86	0	12	3
Thames Navigation, from Inglesham to Oxford	90	0	14	0
Do. from Oxford to London	109	0	17	8
Trent Navigation	72	6	14	6
Union Canal	70	0	14	6
Weaver Navigation	65	0	16	9
Wigan and Leigh Branch of Leeds and Liverpool Canal	76	0	15	2

Each navigation, contained in the before-mentioned table, is of sufficient capacity to receive steam boats adapted to the carriage of goods, if constructed with stern paddles, such as represented in Plate IV. They are also calculated to receive light passage boats of the twin form, moving at a high rate of velocity, and built on the principle of the "Lord Dundas," as shewn in the title-page of this work.

In canals, such as the Chesterfield, Cromford, Grand Trunk, Huddersfield, Macclesfield, Peak-Forest, &c. little can be gained by the substitution of steam, in place of animal power, as on them and similar navigations, there are no data or experiments on which to form an opinion as to what, if any, advantage could be obtained, by a change in the system of trackage. Much, however, might be done, even on narrow canals, in the conveyance of passengers, provided light iron boats were employed, and worked by horses in the same manner as the boat on the Ardrossan Canal, which is now in regular use, plying between Glasgow and Johnstone, at the rate of from nine to ten miles an hour. As regards a boat having a loco-motive engine, and prepared exclusively as a dragging power for flats at a

low rate of speed, it is impossible to say how far such a principle of trackage might answer; as every thing would depend on the shape of the boat, the efficacy of the engine, and the action of the paddles, in a channel so narrow as only to admit boats of no greater width than seven feet on the beam.

I shall conclude by observing, that the field for improvement in canal, and river steam navigation, appears to me most extensive; and if pursued with a proper attention to the lightness and strength of the iron employed in the construction of boats, and the proper disposition of the material, so as to obtain from a given quantity the greatest possible strength, no one can limit the amount of improvement which may thus be obtained in a few years.

APPENDIX.

Before entering upon the details of the experiments referred to in the narrative, it may here be proper to explain in what manner those experiments were made, and the various results obtained.

Plate II is a plan and side view of the twin boat, Swift, provided with a dynamometer, fixed near to the bows. During the experiments she was loaded with people and iron, equal to a gross weight (boat and cargo) of 5 tons, 16 cwt. 1 qr. and 14lbs.

A mile having been carefully measured on the banks of the Forth and Clyde Canal, and proper marks set up at each end, the horses were attached to the line, hooked to the extremity of the lower arm of the bell crank (*a*), which, by means of a cross head, and connecting chains (*b*), forced down the plunger upon the mercury, and thereby caused a rise in the vertical tube, indicating the pressure on the graduated scale in lbs. from 1 to 500.

At the commencement, and during a considerable portion of the first day's experi-

ments, great irregularity was produced by the jerking motion of the horses: to remedy this defect, a person was stationed close to the tube, with a stop watch, to give the time of starting; a second person, with instructions, to call the time at stated intervals, say every 30 seconds; and a third, to give the force in lbs. as indicated on the scale attached to the tube. These preparations having been completed, the horses were got up as nearly as possible to the required speed before reaching the starting point; and the moment the signal was given, the calls commenced, and continued to the end of the distance. The number of calls having been ascertained, with the number of lbs. pressure to each, the whole was added together, and the sum produced divided by the number of calls, which, it will clearly be seen, gave the mean of the forces exerted by the horses during the time employed, and the distance performed respectively.

The first day's experiments are as follow:

NOTE OF A SERIES OF EXPERIMENTS,

Made on the Forth and Clyde Canal, with Mr. Grahame's Twin Boat, Swift, on Friday, the 9th of July, 1830.

No. 1.

Temperature 59°

No. of Experiments.	Weight of Boat and Cargo.			Draught of Water, in Inches.			No. of Horses	Miles on Canal.	TIME.		Miles per Hour.	Force of Traction in lbs.	Average width of Canal.		Average depth of Canal.		REMARKS.
	Cwt.	qrs.	lbs.	Bow.	Stern.	Mean.			Min.	Sec.			Ft.	In.	Ft.	In.	
1	116	1	14	14½	16½	15½	2	1	14	28	4. 14	54. 40	63	,,	9	9	Against the wind, light breeze.
2	,,	,,	,,	,,	,,	,,	,,	,,	14	15	4. 21	34. 00	,,	,,	,,	,,	With the wind.
3	,,	,,	,,	,,	,,	,,	,,	,,	9	45	6. 15	128. 70	,,	,,	,,	,,	Against the wind, a ripple was observed rising at the bows, and extending to the banks on each side of the canal.
4	,,	,,	,,	,,	,,	,,	,,	,,	9	35	6. 26	93. 80	,,	,,	,,	,,	With the wind, ripple the same.
5	,,	,,	,,	,,	,,	,,	,,	,,	8	,,	7. 50	207. 50	,,	,,	,,	,,	Against the wind, with a slight surge at stern.
6	,,	,,	,,	15½	16½	16	,,	,,	7	50	7. 65	202. 35	,,	,,	,,	,,	With the wind, surge the same.
7	,,	,,	,,	16	16	16	,,	,,	7	29	8. 01	264. 30	,,	,,	,,	,,	Against the wind, the surge a little increased.
8	,,	,,	,,	,,	,,	,,	,,	,,	6	28	9. 27	272. 20	,,	,,	,,	,,	With the wind, surge the same.
9	,,	,,	,,	14½	15½	15	,,	,,	7	22	8. 14	266. 50	,,	,,	,,	,,	No sensible difference in surge.
10	,,	,,	,,	,,	,,	,,	,,	,,	7	35	7. 91	243. 20	,,	,,	,,	,,	Wind nearly subsided—surge the same.
11	,,	,,	,,	,,	,,	,,	,,	,,	7	6	8. 45	328. 00	,,	,,	,,	,,	Rather more surge at stern.
12	,,	,,	,,	,,	,,	,,	,,	,,	7	17	8. 23	298. 00	,,	,,	,,	,,	,, ,, ,, ,, ,,
13*	,,	,,	,,	,,	,,	,,	4	,,	4	52	12. 32	410 lbs.	,,	,,	,,	,,	Surge decreased.
14	61	2	7	7	9	8	4	,,	4	16	14. 06	352. 6	,,	,,	,,	,,	In this experiment the surge was greatly diminished—a rippling wave only seen at the stern, and not the least surge in front of the boat.

* The mercury stood fixed in this experiment at 410 lbs.

The preceding table presents several discrepances in the amount of expended power, compared with the velocities obtained, which are accounted for by the head wind, and irregularities produced by the jerking motion of the horses on the dynamometer. These discrepances I have arranged in their regular order; they are as follow:—

No. 1 Experiment,	4. 14	Miles, gives a force of	54. 4	lbs.
2 Do.	4. 21	,, ,, ,, ,,	34. —	,,
Difference of speed	— 07	Difference of force	20. 4	
No. 3 Experiment,	6. 15	Miles, gives a force of	128. 7	lbs.
4 Do.	6. 26	,, ,, ,, ,,	93. 8	,,
Difference	— 11	Difference	34. 9	
No. 5 Experiment,	7. 50	Miles, gives a force of	207. 50	lbs.
6 Do.	7. 65	,, ,, ,, ,,	202. 35	,,
Difference	— 15	Difference	5. 15	
No. 7 Experiment,	8. 01	Miles, gives a force of	264. 3	lbs.
8 Do.	9. 27	,, ,, ,, ,,	272. 2	,,
Difference	1. 26	Difference	7. 9	
No. 9 Experiment,	8. 14	Miles, gives a force of	266. 5	lbs.
10 Do.	7. 91	,, ,, ,, ,,	243. 2	,,
Difference	— 23	Difference	23. 3	
No. 11 Experiment,	8. 45	Miles, gives a force of	328. —	lbs.
12 Do.	8. 23	,, ,, ,, ,,	298. —	,,
Difference	— 22	Difference	30. —	

NOTE OF AVERAGES OF THE EXPERIMENTS

[Contained in the foregoing Table, including the required number of Horses' Power, calculated from a datum of thirty three thousand pounds raised one foot high in a minute.

No. 2.

No. of Experiments.	Time in performing one Mile. Min.	Sec.	Miles per Hour.	Force of Traction.	Horses Power.	REMARKS.
1 & 2	14	20	4.17	44.20	0.491	The surface of water perfectly smooth.
3 & 4	9	40	6.20	111.25	1.839	A rippling wave extending to the banks of the canal.
5 & 6	7	55	7.57	204.92	4.136	A surge at the stern.
7 & 8	6	58	8.64	268.25	6.180	The surge a little increased.
9 & 10	7	28	8.02	254.85	5.450	No change in surge.
11 & 12	7	11	8.34	313.00	6.961	Rather more surge.
13*	4	52	12.32	——	——	The mercury stood in tube—surge decreased.
14†	14	16	14.06	352.6	13.220	Surge greatly diminished.

* No. 13 Experiment was lost, in consequence of a deficiency in the supply of mercury, which stood at 410 lbs. in the tube.
† In No. 14 Experiment, 14 miles per hour, the boat was lighted of a considerable portion of her cargo, and the horses put to their utmost stretch of speed.

It will here be seen, that the boat going at the rates 4.17—6.20—7.57—8.64, &c. required a force in the ratio of 44.20—111.25—204.92—268.25, &c. which is even greater than the squares of the velocities; these proportions are, however, produced at a rate of speed under what is requisite to get clear of the surge, and this, in a great measure, accounts for the disparity of the forces compared with the velocities: in the higher rates of speed, nine or ten miles an hour, or when the surf or swell does not accumulate before the boat, we have different results, as will be seen, when we come to the experiments on the Monkland Canal.

If we square the velocities, as contained in the above table, we shall have the following proportions, viz.—

MILES.	Squares of Velocities.	FORCES.	Ratio of Squares of Velocities to Forces.
4.17^2)=	17.38	44.20	1: 2.54
6.20^2)=	38.44	111.25	1: 2.89
7.57^2)=	57.30	204.92	1: 3.57
8.64^2)=	74.64	268.25	1: 3.59
8.02^2)=	64.32	254.85	1: 3.96
8.34^2)=	69.55	313.00	1: 4.50

So that the ratios of the forces to the squares of the velocities are as the numbers 2.54—2.89

—3.57—3.59—3.96—4.50, which give a rapidly increasing force in the accelerated velocity of 4.17 to 8.34 miles per hour: the numbers 3.57—3.59—3.96, are to each other nearly in the ratio of the squares of the velocities, while the number 4.50 is considerably above that ratio; which, in a great measure, is attributable to the heavy swell produced in the canal during No. 11 and 12 experiments. This evidently shews that bodies passing through fluids in a confined channel, at a quick velocity, are materially affected by the presence of surge; that considerable retardation is occasioned by this circumstance; and great increase of force is hence necessary to overcome the additional resistance.

NOTE OF EXPERIMENTS,

On the 10th July, with the Twin Boat, having a Paddle Wheel in the centre trough 7ft. 6in. diameter, and 2ft. wide.

No. 3.

No. of Experiments.	Distance of Miles.	TIME.		No. of Men.	Revolutions of Paddles.	Diameter of Paddle Wheel.		REMARKS.
		Min.	Sec.			Ft.	In.	
1	¼	4	35	4	,,	7	6	The men worked under very disadvantageous circumstances from the position in which they stood. In 4th experiment the boat was dragged by men, the paddle wheel revolving at nearly the velocity of the boat.
2	¼	3	45	8	,,	7	6	
3	¼	3	45	4	104	7	6	
4	¼	3	,,	4 Dragging	,,	7	6	
—	—	—	—		—	—		

The experiments contained in the above table were made with a temporary paddle wheel fixed in the centre trough, and worked by men; the object of the experiments was more to shew the effect or action of the paddle wheel in the trough, than to ascertain the force necessary to propel the boat.

NOTE OF EXPERIMENTS,

Made with the Twin Boat on the Monkland Canal, on the 12th of July, 1830.

No. 4.

No. of Experiments.	Weight of Boat and Cargo.			Draught of Water, in Inches.			No. of Horses	Miles on Canal.	TIME.		Miles per Hour.	Force of Traction.	Average width of Canal.	Average depth of Canal.	REMARKS.
	Cwt.	qrs.	lbs.	Bow.	Stern.	Mean.			Min.	Sec.		lbs.	Feet. In.	Feet. In	
1	108	2	24	14½	16	15¼	3	¼	3	5	4.86	72.0	40 ,,	5 4	With the wind, and no surge.
2	,,	,,	,,	,,	,,	,,	3	¼	3	7	4.81	92.0	,, ,,	,, ,,	Against the wind, no surge.
3	,,	,,	,,	,,	,,	,,	3	¼	2	23	6.29	191.3	,, ,,	,, ,,	With the wind, a slight surge.
4	,,	,,	,,	,,	,,	,,	3	¼	2	26	6.16	219.3	,, ,,	,, ,,	Rather more wind a-head, with a slight surge at stern.
5	,,	,,	,,	,,	,,	,,	3	¼	2	11	6.87	389.0	,, ,,	,, ,,	With the wind, same swell.
6	,,	,,	,,	,,	,,	,,	3	¼	1	57	7.69	368.1	,, ,,	,, ,,	Against the wind, a swell in front and stern, rolling over the banks of the canal.
7	,,	,,	,,	,,	,,	,,	3	¼	1	21	11.11	420.0	,, ,,	,, ,,	With the wind, no surge.
8	,,	,,	,,	,,	,,	,,	3	¼	1	14	12.16	446.9	,, ,,	,, ,,	No surge—wind subsided.
9	,,	,,	,,	,,	,,	,,	3	¼	1	12	12.50	439.3	,, ,,	,, ,,	No wind, and no surge.
10	57	,,	9	The draught not measured.			3	¼	1	9	13.04	390.0	,, ,,	,, ,,	Light breeze a-head, no surge: a part of the cargo removed from the boat.

In No. 2 experiment, a great part of the cargo was removed from the boat, when thirteen miles an hour were obtained. It will be observed that the whole of the experiments on the Monkland Canal, are less in the proportion of the forces to the time and distance, than on that of the Forth and Clyde.

NOTE OF AVERAGES OF THE EXPERIMENTS,
Made with the Twin Boat on the Monkland Canal, 12th July, 1830.
No. 5.

No. of Experiments.	Time in performing One Mile.		Miles per Hour.	Force of Traction.	Horses' Power.	REMARKS.
	Min.	Sec.				
1 & 2	12	24	4.83	82.0	1.000	No swell.
3 & 4	9	38	6.23	205.3	3.410	Swell a little diminished.
5 & 6	8	16	7.28	378.5	7.842	A swell in front & at stern.
7 & 8	5	10	11.63	433.4	13.490	No surge.
9	4	48	12.50	439.3	14.643	
10	4	36	13.04	390.0	13.936	

From the averages arranged in the above table, it will be observed, that the rates of velocity are to the forces as 4.8—6.2—7.2—11.6, &c. to 82.—205—378—433, &c.; which are less than the squares of the velocities, at the rate of 11½ and 12½ miles per hour, at which time the surge is overcome, and when the boat is moved forward, unaccompanied by the heavy swell that is invariably present at a speed varying from five to eight and a half miles per hour; but this will be more clearly

observed by the ratios of the squares of the velocities to the forces, as under:—

MILES.	Squares of Velocities.	FORCES.	Ratio of Squares of Velocities to Forces.
$(4.8)^2=$	23	82	1: 3.5
$(6.2)^2=$	38	205	1: 5.4
$(7.2)^2=$	53	378	1: 7.1
$(11.6)^2=$	134	433	1: 3.2
$(12.5)^2=$	156	439	1: 2.8

If the ratios of the forces had been as the squares of the velocities, the numbers 3.5—5.4—7.1—3.2—2.8, should have been equal to each other: whereas only the 4.8 and 11.6 mile forces approach to that ratio; the intermediate speeds having forces above, and in an increasing ratio, and those of 12.5 miles in a decreasing ratio.

It appears, that the force required to draw a boat of this form, 11½ to 12½ miles per hour, is not much increased from that of 7¼ miles; the increase being little more than one-seventh, or 55 to 61 lbs. above 378; but horses are unfit for this purpose, as their strength decreases in a much greater proportion than their speed increases; and with these quick velocities great exhaustion is produced, and a considerable por-

tion of their muscular strength is expended in carrying themselves forward only.

Our knowledge of the power of horses drawing at different speeds is very limited; but if we search for it by the formula, which has been most commonly used, and which applies to other agents, as well as to animal power, we have—

$$f = F\left(1 - \frac{v}{W}\right)^2,$$

where F denotes the whole force of the horse when it has no velocity, W its utmost velocity when drawing nothing, v any other velocity, and f the effort answering to it. Then if we assume $W = 18$ miles per hour, and $F = 420$ lbs. we shall have—

	Velocities.		Miles per Hour.		Forces.		lbs.
If	v	=	0	....	f	=	420
,,	v	=	3	....	f	=	291
,,	v	=	6	....	f	=	187
,,	v	=	9	....	f	=	105
,,	v	=	12	....	f	=	47
,,	v	=	15	....	f	=	12
,,	v	=	18	....	f	=	0

From this it would appear, that with half his utmost speed a horse loses 3-4ths of his power; and with 2-3ds of his greatest speed, he would only be able to draw 1-9th: which,

if any reliance can be placed in the theorem, shews clearly the unfitness of horses for great speeds.

Our experiments gave a much greater pressure than 47 lbs. for a velocity of 12 miles per hour, but it was only such as could have been maintained for a very short time, and the weights above are probably quite as great as would be found to be sustained in practice.

NOTE OF EXPERIMENTS,

Made with the Twin Boat on the Forth and Clyde Canal, on Tuesday, the 13th of July, **1830.**

No. 6.

No. of Experiments.	Weight of Boat and Cargo, including Paddles, Boxes, &c. &c.			Draught of Water.			No. of Horses	Miles on Canal.	TIME.		Miles per Hour.	Force of Traction.	Average Width of Canal.		Average Depth of Canal.		REMARKS.
	Cwt.	qrs.	lbs.	Bow.	Stern.	Mean.			Min.	Sec.			Feet	Inches	Feet.	Inches	
1	109	2	10	$14\frac{1}{2}$	$16\frac{1}{2}$	$15\frac{1}{2}$	3	$\frac{1}{4}$	1	20	11.2	473	63	,,	9	9	With the wind, no surge in front, but a slight wave or ripple at the stern.
2	109	2	10	$14\frac{1}{2}$	$16\frac{1}{2}$	$15\frac{1}{2}$	3	$\frac{1}{4}$	1	22	10.9	The Mercury stood the full height in the tube.	63	,,	9	9	Against the wind, no sensible surge—the ripple at stern as before.

The second experiment was lost in consequence of the Mercury standing stationary in the tube. On the Monkland Canal, which is only 40 feet wide, a less comparative force was necessary to drag the boat forward, at 11.11 miles an hour, than on the Forth and Clyde Canal, which is 63 feet wide, at 11.2 miles an hour: this will be observed by comparing the 7th experiment, in No. 4 table, with the 1st experiment, in No. 6 table.

NOTE OF EXPERIMENTS,

Made on Tuesday the 13th of July, 1830, with Paddles on the side of the Boat:—area of each Paddle the same as those on the Wheel used in the centre Trough on the 10th of July.

No. 7.

No. of Experiments.	Weight of Boat and Cargo, including Paddles, Boxes, &c.			Draught of Water.			No. of Men at Cranks	Miles on Canal.	TIME.		Miles per Hour.	Average Width of Canal.		Average Depth of Canal.		REMARKS.
	Cwt.	qrs.	lbs.	Bow.	Stern.	Mean.			Min.	Sec.		Feet.	Inches.	Feet.	Inches.	
1	109	2	20	14½	16	15¼	16	¼	2	36	5. 7	63	”	9	9	With the wind, no surge, the paddle working without much agitation in the water.
2	”	”	”	”	”	”	”	”	2	36	5. 7	”	”	”	”	Against the wind, the men worked better this trip.
3	”	”	”	”	”	”	”	”	2	17	6.50	”	”	”	”	With the wind, the men still improving in working the paddles—surge the same as in the first and second experiments.
4	”	”	”	”	”	”	8	”	3	13	4.66	”	”	”	”	With the wind, no surge.
5	81	3	24	13	15	14	16	”	2	8	7.03	”	”	”	”	The boat lighted of part of her cargo, with the wind—no sensible surge.
6	”	”	”	”	”	”	”	”	2	38	5.69	”	”	”	”	Against the wind, and without surge.

When making the experiments with the single paddle-wheel in the centre, as detailed in No. 3 table, it was found, from the defective state of the machinery, that little more could be done than to shew the action of the float boards in the trough, and the consequent wash that might be produced on the banks. It should here be observed, that the agitation of the water, occasioned by the wheel working in the trough, never approached the banks, but was discharged from the stern, running like a mill-stream in an extended line for some distance in the middle of the canal.

No. 7 table furnishes the results of subsequent experiments, made with two side paddles of the same dimensions, or double the area of the single middle paddle-wheel, employed on the 10th: in order to see the effect of the side paddles, compared with the wheel confined in the centre trough, little, however, could be learnt by those experiments, as the pull or swing of the men working at the ropes, produced a rocking motion that materially impeded the progress of the boat.

NOTE OF EXPERIMENTS,

Made with the Twin Boat, Swift, with One Centre Paddle of $7\frac{1}{2}$ Feet Diameter, on Wednesday, the 14th July, 1830.

No. 8.

No. of Experiments.	Weight of Boat and Cargo.			Draught of Water.			No. of Men at Cranks	Miles on Canal.	TIME.		Miles per Hour.	Revolution of Paddles	Average Width of Canal.		Average Depth of Canal.		REMARKS.
	Cwt.	qrs.	lbs.	Bow.	Stern.	Mean.			Min.	Sec.			Feet.	Inches.	Feet.	Inches.	
1	112	3	23	15	17	16	12	$\frac{1}{8}$	1	36	4.68	44	63	,,	9	9	No sensible surge was observed during any of these experiments.
2	,,	,,	,,	,,	,,	,,	,,	,,	1	46	4.24	54	,,	,,	,,	,,	
3	,,	,,	,,	,,	,,	,,	,,	,,	1	33	4.83	—	,,	,,	,,	,,	
4	,,	,,	,,	,,	,,	,,	,,	,,	1	46	4.24	57	,,	,,	,,	,,	
5	,,	,,	,,	,,	,,	,,	,,	,,	1	36	4.68	55	,,	,,	,,	,,	
6	66	3	20	8	10	9	,,	,,	1	57	3.84	62	,,	,,	,,	,,	
7	,,	,,	,,	,,	,,	,,	,,	,,	1	35	4.73	62	,,	,,	,,	,,	

From the defective state of the experiments made on the 10th, with the centre paddle, it was deemed advisable to repeat them on a more accurate and extended scale: another set of experiments were, therefore, arranged.—The above table furnishes the results of those trials.

Although sixteen men were employed, half that number only could work at the cranks, and the remaining eight had to pull with ropes: this was a bad application of power, as they could only exert their strength in one direction, and, of course, one-half of their force was entirely lost, from the very ineffective manner in which they had to apply themselves to the work; I therefore deduct four men, and have inserted them in the table as twelve, instead of sixteen, the number actually employed.

At the close of the experiments, the boat was moored or fastened, by the rope attached to the dynamometer, (in the boat) to a bridge over the canal. Eight and sixteen men respectively were then applied to the cranks, with instructions for them to use their greatest possible strength, in order to ascertain the effect on the dynamometer, by their attempt to move the boat; the results are as under:—

Eight men gave a force of 88lbs.
Sixteen.................. 133lbs.

which shews that the power of sixteen men was much less in proportion than that of eight; it must however be observed, that the sixteen men worked under the same disadvantages as related above, and could only be considered as twelve effective workmen.

NOTE OF EXPERIMENTS,

With the Twin Boat, Swift, fully loaded, on Friday the 16th July, 1830.

No. 9.

No. of Experiments.	Weight of Boat and Cargo.			Draught of Water.			No. of Horses	Miles on Canal.	TIME.		Miles per Hour.	Force of Traction.	Average width of Canal.		Average depth of of Canal.		REMARKS.
	Cwt	qrs	lbs.	Bow.	Stern.	Mean.			Min.	Sec.		lbs.	Feet.	In.	Feet.	In.	
1	140	,,	,,	22	25	23½	3	¼	3	8	4.78	115	63	,,	9	9	
2	,,	,,	,,	,,	,,	,,	,,	,,	2	32	5.92	182½	,,	,,	,,	,,	
3	,,	,,	,,	,,	,,	,,	,,	,,	2	11	6.87	234	,,	,,	,,	,,	In these experiments the surges were observed to be nearly the same as produced in those of the 10th of July.
4	,,	,,	,,	,,	,,	,,	,,	,,	2	12	6.81	272	,,	,,	,,	,,	
5	,,	,,	,,	,,	,,	,,	,,	,,	1	53	7.96	410	,,	,,	,,	,,	
6	,,	,,	,,	,,	,,	,,	,,	,,	1	54	7.89	435	,,	,,	,,	,,	
7	,,	,,	,,	,,	,,	,,	,,	,,	1	45	8.57	510	,,	,,	,,	,,	
8	,,	,,	,,	,,	,,	,,	,,	,,	1	50	8.18	456	,,	,,	,,	,,	

During the time of the experiments contained in No. 9 table, a considerable quantity of water was in the boat, which Mr. Hunter estimated at one ton weight.

Before closing this account, I deem it proper in this place to offer my best acknowledgments to the gentlemen who assisted in the experiments, particularly to my much esteemed friend James Smith, Esq., of Deanston; the ingenious Mr. Hart, of Glasgow; Captain Chyne, agent to the Union Canal Company; Mr. Dodds, engineer to the Ballochney and Kirkintilloch Railways; Mr. Murray, engineer to the Forth and Clyde Canal Company; and Mr. Hunter, who built the boat: to all these, and several other gentlemen not named, I am much indebted for their very valuable and gratuitous services.

In page 32 it is asserted, that passengers can be conveyed from Port Dundas, to Port Hopetown, a distance of 56 miles, at a charge to the Canal Company, of not more than two-pence each: to prove that this sum, however small, is nevertheless sufficient for the purpose, I have annexed the following calculation.

Suppose the new iron boat, with a locomotive engine of ten horses' power, to be propelled at the rate of 9½ miles per hour, including stoppages, time for passing the locks, &c.: it will then take six, or six and a half hours on the voyage. Now a locomotive engine working up to ten horses' power, will consume about* 2½ cwt. of coal per hour; consequently we have—

Wear and tear on Engine, Machinery, &c. at 10 per cent. on £980 for one day, supposing 312 working days in the year	0	6	3¼
Engineer and assistant's wages	0	7	6
Coal 16 cwt. at 5s. 6d. per ton	0	4	5
Oil, Tallow, &c.	0	0	9
Sundries	0	0	5
Total charge for conveying, say 116 passengers, 56 miles	£0	19	4¼

19s. 4¼d. reduced to pence, and divided by 116, the number of passengers, gives 2d. the actual expense incurred by the Canal Company for the conveyance of one passenger 56 miles; of course this sum does not include the canal

* I believe 2½ cwt. of coal per hour to be too great an allowance for a locomotive engine working up to 10 horses' power: on the Liverpool and Manchester Railway, a much less proportionate quantity of coal is consumed.

dues, nor does it provide for any diminution of the number of passengers, which will cause an increase or decrease in cost, in proportion to the numbers carried.

Mr. Grahame, in his calculations, makes the charge to the Canal Company for each passenger under 1½d. I have however taken the larger sum 2d. as the real cost, and have calculated on 116 passengers, instead of 150. Mr. Grahame calculates as follows:—

By packing the passengers just as in a coach, we could carry more than 150 passengers, but say 150 from Glasgow to Edinburgh...	150
Also back	150
Number of passengers in one day..........	300

Now taking 312 working days in a year, we have 300 × 312 = 93600, the number of passengers carried in one year.

The sum which these passengers would give at 1d. each, would be 93600 pence, = £390, being £80 higher than Messrs. Walker and Rastrick's estimate of the maintenance, replacement, and expenses of a locomotive engine and tender, doing 120 miles per day, or upwards of 14 hours' work.

If we suppose the boat to be only three-fourths full each trip, then, if each passenger paid 1¼d. the sum received would be £438 15s. in place of £390. Mr. Grahame goes on to observe, "that we could get our captain, steersman, and steward for nothing, or in fact, a rent for these places, if we give them the right to sell refreshments:" he further says, "I know it may not be our intention to allow more than 100 passengers, or even fewer to go by the boats; but if we limit their power of carriage to give conveniences, not enjoyed in other conveyances, this does not limit the power of the boat; you must recollect, that 84 passengers have come through in the Swift boat from Edinburgh, and there is more room lost in her lesser length of 60 feet in the steward's place, than in your engine."

There is no calculation of the cost of steam, compared with trackage by horses, on canals adapted to the introduction of steam as a moving power,—such as the Forth and Clyde, the Mersey and Irwell Navigation, the Duke of Bridgewater's Canal, the Union Canal, &c.—Mr. Grahame has, however, supplied me with data, on which to found a comparative estimate.

At present, the passage of goods between Port Dundas and Port Hopetown, is accomplished in a period of from 18 to 20 hours; and in order to have a delivery each day, the company trading between these two ports, are obliged to employ four boats, navigated by two men each, with a spare boat for the accommodation of the grain trade, in order to give the merchants the requisite time for loading and delivery.

The largest cargo carried by any one of these boats, during the last two years, was about thirty-eight tons; the charges on this are as follow:—

Wages of crew	£ 364	3	4
Trackage	676	15	8
Track ropes	81	15	10
Making a charge of	£1122	14	10

for the conveyance of thirty-eight tons delivered each day at Port Hopetown, and thirty-eight tons each day at Port Dundas. Now if we calculate, as before, 312 working days in the year, it gives $38 \times 2 \times 312 = 23712$ tons delivered at Port Hopetown and Port Dundas in one year, which is equal to 11¼d. per ton for 56 miles, or under a farthing per ton per mile.

Let us now consider, at what cost the same quantity of goods can be delivered by a Steamer adapted to the canal, carrying the same weight of cargo, and propelled by a ten-horse engine:—if we take tear and wear on the engine, at the same rate as on the passage-boat, it will be—

Wear and tear on £980, at 10 per cent.	£ 98	0	0
Coal, 400 tons, at 5s. 6d.	110	0	0
Engineer and assistant's wages*	107	0	0
Oil, tallow, hemp, &c.	15	0	0
	£330	0	0

the actual sum required to deliver 11856 tons of goods, conveyed a distance of 56 miles, being about a 1-9th of a penny per ton per mile.

The above is estimated on the principle that two steamers are employed to do the same work as four flats; that the voyage should be made in 14 instead of 18 or 20 hours, which would produce a saving in time of from four to six hours each voyage, and would give perfect certainty as to the arrival and departure of the

* I have computed the engineer's wages at £70, and his assistant at £37 per annum, which, by many will be considered a liberal allowance.

vessels at both ends of the line:—now as two steam boats are capable of doing the work of four flats, it will then be double the amount of charge £330, or £660 for steam-power, instead of £758 : 11 : 6, thecharge for trackage, equal to a saving of £98 : 11 : 6; but £98 11 : 6 is not the only saving, as two vessels would be employed instead of four, and of course a saving of half the crew, or £182 : 1 : 8, making in the whole an annual saving of £280 13 : 2, or one-fourth in favour of steam-power, exclusive of the great saving in time.

Mr. Grahame calculates this differently, and draws the comparison between animal and steam-power, as follows:—

"As to the expense of this new mode of conveyance, (meaning steam) it may be proper before considering it, to calculate the amount now laid out, and on which a saving is to be effected.

The first and principal of these items is trackage, and the amount is		£676 15 8
The next item is track ropes, and the amount is....	£81 15 10	
As there must, however, be a short line for towing the spare grain boat, we will deduct on this account..	11 15 10	70 0 0
The last item is the wages of the men employed in the four boats	364 3 4	
And, as the whole work will now be done by two steam boats, and as a steersman will only be required in the grain boat, one half of the same may be saved.	182 1 8	182 1 8
		£928 17 4

The question therefore at issue is, will a sum of £928 : 17 : 4 pay the wear and tear on two steam engines of ten horses' power; the wages of the engine-man, and boys; the coal, grease, oil, &c. requisite to keep the engines going. I have no hesitation in saying, that one half of that sum would easily pay all the above outlays. The estimate of the annual expense of keeping up a locomotive

engine and its carriage, with the accompanying tender to carry water and coals, is stated by Messrs. Walker and Rastrick, in their report to the Liverpool Railway Committee, to be £311 : 8 : 4, and the following are the items of which this charge is composed :—

" For estimated annual repairs. A tube and chimney breast, a peice every three years, or annually..	£12	10	0			
Occasional repairs to boilers..	£ 3	0	0			
New chimney each year, and deduct old............	7	10	0			
Set of chimney bars every two months............	6	0	0			
Axles and brasses, one set annually..............	10	0	0			
Wheels....................	36	0	0			
Tender, carriage, and tank..	2	10	0			
Small repairs	12	0	0			
				£89	10	0
Add one-fifth for spare engine............				17	18	0
For wages, coal, and other working expenses.						
Engine-man's wages, at 21s. per week	54	12	0			
Boy to assist............ ..	26	0	0			
Coal, 382 tons, at 5s. 10d...	111	8	4			
Grease, oil, hemp, &c.	12	0	0			
				204	0	4
				£311	8	4

I might state that the above items are, by Mr. Stephenson, the engineer of the Liverpool and Manchester Railway, asserted to be too much; and I might also deduct the items for renewal of wheels, repairs of tender, &c.; but I am ready to take the statement of Messrs. Walker and Rastrick as under, rather than above the mark, and to allow all the charges for wheels, tender, carriage, &c. applicable solely to an engine working on wheels, and which has to carry its coal and water in a separate carriage. To make up this calculation, after all, the total expense of two engines would be £622 : 16 : 8, and there would be a saving of one-third out of the £928 : 17 : 4 or £306 : 0 : 8 each year.

I have not said anything in the foregoing statement as to the repairs of the boats, as it is common to both modes of conveyance; only there is a saving of the repairs on two, out of the five boats, by the use of steam. In fact, by the steaming plan, the present number of boats might be reduced one-half, instead of increasing them in the same ratio, and accomplish with this diminished number of boats, a much greater quantity of business, with greater dispatch, than could be done by the proposed increased establishment."

The preceding calculations all refer to the comparative cost of animal, to that of steam power: an increase of speed is considered practicable; great regularity is expected to be produced from its introduction, and the transit of goods accomplished at a lower rate of charge, than what is now done on canals by the present mode of towing by horses:—all this is expected, and looked forward to as a consequence of the change intended to be produced, by this new method of working canals. The boats referred to in these calculations, and represented in the drawings, are "self contained;" or, in other words, each boat contains the cargo and steam-engine within herself. Now it is obvious, that much may be accomplished by the use of steam drags; that a vessel, such as is represented in Plate IV, might be usefully employed, not only in towing, but at the same time, might advantageously convey a full cargo of goods to the same destination, as her train of accompanying flats. In fact, I am inclined to think, that this mode of trackage would be found the most eligible that could be adopted, particularly on broad canals, navigable rivers, and where there is a long reach free from the interruption of locks. I am the more convinced of the efficacy of steam trackage, above

all others, from the circumstance that the train of boats intended to be towed, would follow in each other's wake, as the eddy formed by the leading vessel materially lessens the resistance opposed to the succeeding boats; and, if I may use the expression, sucks the towed boat into the vacuity formed by the vessel's progress through the canal. I am the more induced to recommend this principle, from the fact that all leading boats, having a moderate draught of water, and used for the purpose of towing, cause, by their own displacement, a sufficient inlet for towed vessels to fill up the wake, and to move forward, in a ratio equal to the currents, as they flow in the direction of the boat's progress.

The small quantity of power required to tow a vessel, was remarked by Mr. Grahame, in his account of the voyage of the Cyclops from Alloa to Port Dundas: he states, "When we brought her into the canal, we attached her to the passage-boat, and she drew her along the canal two miles,—one mile in fourteen, and the other in fifteen minutes. We then detached her from the passage-boat, and did two other miles, but could not save, by this decrease of labour, more than a minute,

or a minute and a few seconds in each mile. She was then attached to the passage-boat, and dragged on to Port Dundas," &c.

I am not aware that any experiments have ever been made, to ascertain the best principle of towage at a low rate of velocity; or rather, to ascertain the forces requisite to move a train of boats at a moderate speed, three and a half, or four miles an hour, through a line of water confined within the banks of a canal. It appears to me a matter of importance to know, what might be the forces requisite for that purpose; or, whether a chain of boats, connected together "stem and stern," by circular joints, or other means, could not be dragged forward with less resistance, and at less cost, than the present mode of single trackage. I am strongly persuaded that steam-power might be beneficially employed in this way, and that the trade on some navigations might be carried on to great advantage, by a judicious application of the steam drag. It is worth the consideration of Canal Proprietors generally, to ascertain the above facts: they are of some importance, and might lead to a system of trackage infinitely superior, more regular, and much cheaper, than that now in use. One thing is very evident,—that the introduction of steam,

instead of animal power, would dispense with the annual repairs, and maintainance of the horse-paths; the complaints and delays arising from drivers, horses, &c. would be avoided, and many contingent expenses saved, by the introduction of this never-failing and very effective agent, as a moving power for the towage of boats on canals.

In closing these observations, I would direct the reader's attention, and all those interested in Canal Navigation, to a class of vessels calculated to carry on an effective and lucrative trade, not only on canals, but at the same time, to extend their voyages into the open sea, and along the adjoining coasts,—such vessels, in fact, as we have alluded to in the narrative. Plate V is the design of a steam-boat of this description, and intended for this particular trade: her machinery is placed in a different position to the improved boat in Plate IV, and that, for the following reasons, viz.—

A steam-boat, built exclusively for canal and river navigation, is not in every respect calculated for long voyages at sea, particularly if constructed with stern paddles, as represented in Plate IV. It appears to me, that a vessel of this description would be (in her

machinery) exceedingly ineffective in a gale of wind, blowing direct a head or hard aft, if accompanied with a heavy swell: the position of the paddles in this case is objectionable, so far as the working of the wheels would be obstructed by the pitching of the vessel, which is much greater at the prow and stern, than at midships; a running sea, fore and aft, would consequently affect the paddles, as they would be alternately raised when the vessel hung on the sea, and deeply immersed when the top of the swell was passing the stern. I am the more convinced of this circumstance, from the opinion of a gentleman, whose general intelligence and great experience fully entitle him to consideration, in matters connected with this subject.

I am not sufficiently acquainted with what has been done, to know if the stern paddle-vessel, such as described and represented in Plate IV, was ever tried, either at sea, or even in smooth water; or, that its insufficiency was ever proved as a sea-going boat; the objections just stated seem plausible, and will, no doubt, be found of considerable weight when reduced to practice, in the event of the vessel proceeding to sea in stormy weather.

Conceiving, therefore, that paddles at the extreme end of the stern are attended with risk, from the pitching of the vessel in a rough sea, I deemed it expedient to give the subject my best consideration, in order as far as possible to remove the difficulty, and prepare designs for a boat, that would at once pass through the canals, and give perfect security at sea. How far I have succeeded in those attempts, it is not for me to decide: I am, however, anxious to remove, as far as possible, those apparent defects; to combine the advantages of a canal steamer, with the practical usefulness of a vessel constructed for general traffic, and the navigation of the open sea. Persons conversant with nautical affairs, are doubtless more competent to form a correct judgment on these matters, than myself,—as many unforseen difficulties may arise, and many obstacles present themselves, in the prosecution of objects surrounded by so many opposing circumstances, and complexity in the detail. It must, nevertheless, be allowed, that the connection of the sea with our largest and best inland navigations is of much importance, and in my opinion, fully practicable, provided pains are taken to enlarge the locks, (where such enlargement is necessary) and the navigations kept open, for the reception of this particular

class of steamers. I shall now leave the subject in the hands of the discerning reader; fully convinced that the measure is fraught with important consequences to the public, and that its accomplishment will, in a great degree, be beneficial to that portion of the public, whose properties are invested in the different navigations, to which this subject more particularly refers.

DESCRIPTION OF THE PLATES.

PLATE I.

Represents a side view and plan of the "Lord Dundas" Iron Twin Boat; it will not be necessary here to give the dimensions, as a detached account of her length, breadth, weight, &c. is given in the 31st page of this work: suffice it to observe, that she is constructed of exceedingly light material, the plates or sheeting of the iron ribs being under $\frac{1}{16}$ of an inch in thickness, and her whole weight, exclusive of the steam engine, paddle-wheel, &c. not exceeding two and a half tons.

PLATE II.

Is a side view and plan of the experimental Boat "Swift;" her dimensions are as under:—

Whole length, 60 feet.
Breadth on beam, 8 feet 6 inches.
Width of centre trough (extending longitudinally down the middle of the boat) 2 feet 6 inches at the bow, 22 inches at midships, and 3 feet 6 inches at the stern.

The Swift is gig-built, light timbered, and weighs about 27 cwt.

PLATE III.

Conveys nearly a correct representation of the Cyclops now plying on the Forth and Clyde Canal, to Alloa, on the Firth of Forth: this vessel has a fourteen horses' power steam engine, placed in the position A, near the stern; it gives motion to the paddle-wheel, by the connecting rod B: the boiler C is fixed on the opposite side to the engine, and is so arranged as to give room for the man to fire, and space for a sufficient quantity of coal to last the voyage. This boat is built on the American plan, and works, with great steadiness in the canal, at four miles an hour; her dimensions are as follow:—

Whole length, 68 feet.
Breadth on beam, 15 feet 6 inches.
Depth, about 7 feet 3 inches from the keel to the deck.
Weight, including engine, boiler, fittings, &c. about 38 tons.

On examining the side view of the Cyclops, it will be seen that her water lines are shewn,—

First, as represented by the line *a*, when light; that is, with no cargo except a sufficient quantity of water in the boiler, and two tons of coals on board, when her draught was 4 feet 6 inches aft, and 1½ inch forward.

Second, by the line *b*, with a cargo of 20 tons 3 qrs. 17 lbs. her draught being, in this instance, 4 feet aft, and 2 feet 6 inches forward. The loading on this occasion was improperly disposed.

Third, by the line *c*, with a cargo of 29 tons 3 cwt. 3 qrs. 17 lbs. her draught, in this case, being 3 feet 9 inches aft, and 3 feet 6 inches forward.

It has already been remarked by Mr. Grahame, that a cargo, or not a cargo, makes little difference to the Cyclops, as her speed is neither increased, nor much diminished by the change; this, no doubt, is owing to the weight of the engine, boiler, paddle-wheel, &c. raising the bow, and bearing down the stern, when she is light, and sinking the paddle-wheel to a depth that must rather churn the water, than produce an effective impulse, as may be seen by the variation of the water lines *a*, *b*, *c*, which sufficiently illustrates this part of the subject.

PLATE IV.

Represents a side view and plan of the improved iron steam boat, now building for the Forth and Clyde Canal Company: this vessel is intended for the double purpose, of navigating the canal, and the adjoining coasts; the following are her dimensions:—

Whole length, 68 feet.

Breadth on beam, 15 feet.

Depth from the keel to the deck, 8 feet.

Steam engine 24 horses' power, having two cylinders on the locomotive principle: paddle wheels, each 11 feet diameter, and 3 feet wide.

Computed weight of boat, paddle-wheels, engine, &c.

	Tons.	cwt.	qrs.	lbs.
Boat,	10	5	2	0
Engine,	6	2	0	0
Machinery,	2	18	2	9
Rigging, stores, &c.	3	6	0	0
Total weight,	22	12	0	9

This vessel will contain a cargo of 50 tons, on a draught of water of about 3 feet 9 inches; she will be constructed of the best material, with strong iron ribs, and plate sheeting about ¼ inch thick. The same objection may be urged against this boat as the Cyclops, so far as respects her water lines, which, from the position of the steam engine, paddle-wheels, &c. must cause her to hang much by the stern; this objection is of no moment, as vessels of this description seldom sail without some loading; and, at all times, there is the power to trim the cargo, so as to give her the proper bearing in the water. I therefore deem the weight of machinery at the stern of less consequence, than the loss of power and inconvenience of conveying the motion from the engine (if placed nearer the bows) to the wheels, in that position: besides, placing the engine nearer the middle of the hold, would in a great measure destroy valuable stowage, and materially limit her carrying capacity.

PLATE V.

Is a side view and plan of a Canal Steamer, calculated for sea voyages, and a direct communication with the internal parts of the country, through canals constructed for the admission of such vessels: it will be seen, that a part of the side of the boat is supposed to be cut out, for the purpose of representing a sectional view of her steam engine, paddle-wheels, boiler, &c. A slight glance at the plate will shew, that the wheels are advanced nearer midships; that considerable care is taken to occupy as little space as possible in the vessel; that the whole machinery is exceedingly compact, and takes up no more of the vessel's stowage than 21 feet in length, including space for firing, and room to stop and start the engine. The paddle-wheels are placed in the position H, to obviate the apprehended danger and difficulty of working them advantageously at sea, and also, to retain them as near the stern as possible, on account of saving the vessel's bearings, and allowing a free discharge from the wheels when her portcullises are down, which would always be the case in passing through the canal.

The dimensions are as under, viz :—

Whole length, 88 feet.

Breadth on beam, 20 feet.

Depth from the keel to the deck, 9 feet.

Steam engine (high pressure) 60 horses' power, having two cylinders as per plan.

Paddle-wheels, 12 feet diameter each, and 4 feet wide.

Computed Weight.

	Tons.	cwt.	qrs.	lbs.
Boat, composed of strong-ribbed iron and plates, $\frac{5}{16}$ inch thick	21	14	3	0
Steam-engine, boiler, &c.............	12	10	0	0
Paddle-wheels, &c....................	3	10	0	0
Rigging, stores, &c..................	8	10	0	0
Total weight........Tons.	46	4	3	0

Carrying power, draught of water, &c. will be—

	Burthen. Tons.	Draught of Water. Feet.	In.
When light, including engines and coals under forecastle, equal to a cargo of....................	10	2	0
With a cargo of....................	48	3	0
With a cargo of....................	92	4	0
With a cargo of.........	116	4	6

So that a full cargo of 116 tons would give a draught of water, four feet six inches, which I apprehend is not too much for most canals communicating with the different sea ports on the coast.

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